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CARISMA
Innovation for Climate Change Mitigation

CARISMA Climate Change Mitigation Monitor

LIFE CYCLE EMISSIONS OF CLIMATE CHANGE MITIGATION OPTIONS: ARTIFICIAL TREES AND RENEWABLE ENERGY

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RU assesses net environmental benefits and trade-offs of technology options from a life-cycle perspective.

Life cycle greenhouse gas (GHG) emissions of artificial trees and three sustainable energy technologies have been assessed in the CARISMA project.

In order to keep the world on track for below 2°C (or 1.5°C) of warming, low-emission, zero-emission, or even negative-emission technology is needed. However, manufacturing, installation, operation, and maintenance of these technologies also lead to emissions. CARISMA has therefore assessed the life-cycle emissions of such technologies, using artificial trees and three sustainable energy technologies as illustration.

ARTIFICIAL TREES

Direct air capture (DAC), also known as artificial trees, is a climate change mitigation option in the experimental stage, capturing CO_2 from ambient air. As this option works independently of energy technologies, it has caught the attention of policy makers.

A DAC system captures atmospheric air by forcing it through a filter. This filter is covered with a chemical sorbent that reacts with CO_2. The saturated filter is treated so that the captured

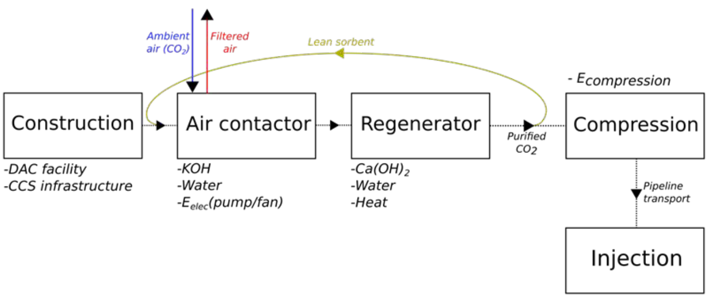

Figure 1. Flowchart of general DAC full life cycle. The DAC system consist of an air contactor, where CO_2 is extracted by binding it to the sorbent, a regeneration facility where the sorbent is treated and the CO_2 is separated, compression facility, CO_2 transport and injection facility.

CO_2 is separated in order to store it (see Figure 1). DAC can potentially lead to a net removal of CO_2 from the atmosphere. We calculated the carbon efficiency of DAC, defined as (GHGcapture – GHGinvestment)/GHGcapture. GHG capture is the amount of CO_2 captured by the device and GHGinvestment is the life cycle CO_2 emissions to construct and operate the device. Only carbon efficiencies greater than 0 would imply net negative CO_2 emissions.

For the DAC assessment, several scenarios were examined based on chemical recycling rates and energy requirements. All scenarios lead to negative carbon efficiencies (Ec = -1.25 and Ec = -0.26 for the worst and averaged scenarios, respectively), except for the most optimistic scenario (Ec = 0.30), in which nearly all chemicals are recycled (95% compared to 85% in the averaged scenario) and the device is powered by a combination of hydropower and natural gas.

From these results we conclude that the experimental DAC system which we analysed requires more CO_2 'investment' than it can store. In other words, our scenarios point into the direction that the GHGs emitted during construction and operation may never be displaced by the DAC device. This implies that a technological breakthrough in the type and amount of absorbent and energy is required to make DAC a mitigation option with negative net emissions.

RENEWABLY ENERGY SOURCES

We have also analysed a number of renewable energy sources in terms of electricity production with respect to their life cycle GHG emissions: wind, solar, and bioenergy with ►

carbon capture and storage (BECCS). The same metric was used for all three energy technologies in order to enable comparison: GHG payback time (GPT). This metric represents the time it takes for total GHG emission reduction (e.g. renewable instead of fossil fuel-based energy) to match the emissions related to its production, transport, and installation.

The GPT calculations for wind and solar were determined taking local climatology into account. For wind energy, we specifically investigated the GPT of 4,081 onshore and 80 offshore wind farms in Northwest Europe. GHG life cycle emissions of the construction of the wind turbine were estimated on the basis of rotor diameter and hub height with scaling relations newly developed in the project. Spatial and time explicit wind speed information was derived from the KNMI North Sea Wind (KNW) atlas; a validated, high-resolution wind dataset. For solar energy, spatial differences in the solar irradiation on the global scale were included, using a dataset from NASA, while life cycle GHG emissions of the construction of the solar PV installation were based on data from the Ecoinvent life cycle database. For BECCS, initial GHG emissions are due to land-use change. Lifecycle GHG emissions were derived from a literature review of pre-existing life cycle assessments.

Figure 2 shows the mean GPT of the three technologies. The bars denote the minimum and maximum GPT. Wind energy has the smallest GHG payback time, with on average 4 months (i.e. within 4 months emission reductions due to replacing fossil fuels outweigh the technology's life cycle emissions). The range in GPTs for the wind farm is mainly caused by spatial differences in wind climatology. The results confirm that larger turbines have lower GPTs, but compared to differences in climatology, turbine size is less influential.

Solar panels show average payback times of approximately 3 years. The variation in the GPT is caused by differences in solar radiation, which ranges from 1.7 to 7.4 kWh/m^2/day. Furthermore, while we recognise that solar and wind farms are both technologies that produce intermittently, we have not taken into account the GHG emissions that would result from backing up excess peak electricity production.

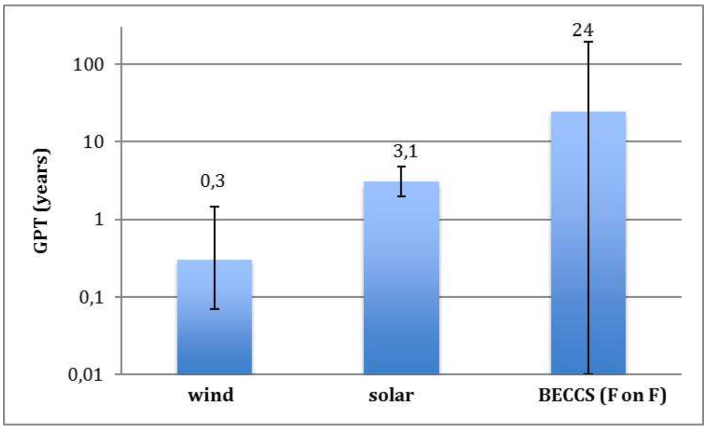

Figure 2. Mean GPTs for wind, solar and BECCS. Error bars denote the full range of GPTs. The GPTs of BECCS are shown for the forest on former forestland scenario. We use a global warming potential (GWP) of 0.6 kg CO2-eq/kWh as a reference benchmark, which is based on the average electricity generation of 55 different countries.

The GPTs for BECCS are shown for forest on former forestland. This scenario is quite common for bioenergy. While the mean GPT is high, with 24 years, the range is also very large. The variation in the GPT is controlled by the former land use, and the yield. It is important to note that while this is a common scenario, it most certainly is not the most optimal one. This can be seen in Figure 3, which shows the GPTs for three crop types on former forestland and former grasslands. Scenarios based on grasslands as former land use have much lower GPTs, in the order of 0-1 years.

CONCLUSIONS

To conclude, DAC only leads to negative emissions under the most optimal conditions, and as such does not seem to be a promising mitigation option. However, once the carbon efficiency is greater than zero, DAC quickly becomes interesting from a GHG performance point of view. Of the three sustainable energy technologies described here, wind energy has the lowest GPTs, but BECCS has the potential for the lowest GPTs, if attention is paid to former land use and crop type.

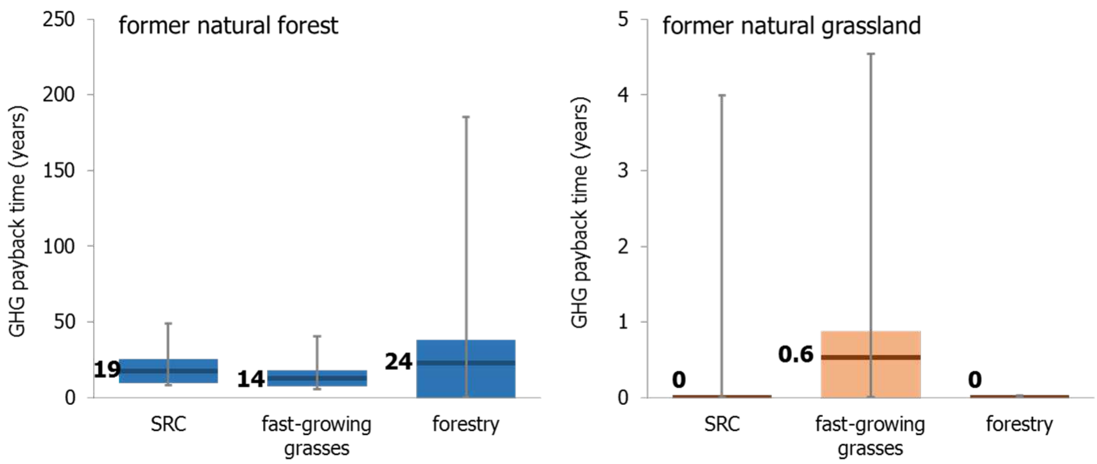

Figure 3. GPTs of bioenergy with CCS. GPTs are given for three crop types (short-rotation coppicing (SRC), fast-growing grasses, and plantation forestry), while considering two types of land-use change; natural forest to bioenergy (a) and natural grassland to bioenergy (b). Colored bars indicate the typical range, while the darkest colour indicates average value. Error bars indicate extreme values.

COLLABORATIVE **R&I** INITIATIVES **ACROSS BORDERS**

As part of the CARISMA project, Radboud University and the UNEP DTU Partnership hosted a workshop in Amsterdam to discuss international research and innovation (R&I) initiatives taking into account the main actors and organisations involved in: (i) regional-level R&I initiatives; (ii) government-to-government R&I initiatives; and (iii) industry-specific R&I initiatives. Representatives from academia, government, international institutions, industry associations and the private sector were present to share experiences and insights.

International R&I workshop in Amsterdam, 20 February 2017 .

From the workshop it became apparent from both the presentations and the subsequent discussions that there is a need for more clarity when it comes to defining the difference between research and development (R&D) on the one hand and innovation on the other hand. Too often, these concepts are used interchangeably, while they mean different things. R&D is clearly about supporting a technology through the early stage of a learning curve, while innovation is about all that needs to be done for succesful deployment and diffusion at desired scale.

The research done by the partners of the CARISMA project furthermore revealed that mapping R&I initiatives is a challenge. Feedback from the participants at the workshop indicated that a case study approach would provide more detailed insights. A suggestion was made by the research team to establish a common database for all member states to register their initiatives.

A final take-home message from the workshop was that technology cooperation cannot be put into a replicable, optimal framework, as it requires flexibility, improvisation and endurance and will need to have heterogeneous key performance indicators. Moreover, technology cooperation should not be seen as stand-alone, but rather seen as integrated with other important policy aspects. All PowerPoint presentations from the workshop can be downloaded from the CARISMA website.

BREAKING DOWN THE SILOS OF CLIMATE ACTION

Just days before US president Donald Trump decided to dismantle Barack Obama's Clean Power Plan, the Stockholm Environment Institute (SEI) organised (27 March of this year) a CARISMA roundtable discussion on the research, policy and business of climate change mitigation in the European Union. Despite the growing scientific evidence of human-induced global warming, and mitigation and adaptation technologies and policies becoming more sophisticated, climate action still underachieves and remains insufficient to meet the 2°C target set by the Paris Agreement.

One of the reasons is the increasing silo mentality amongst the different stakeholders. Researchers talk largely among themselves, the gap between policy makers and the demands of their constituencies is growing, and for many businesses climate change is not the main priority. The main objective of the roundtable was therefore to break down silos and to facilitate a dialogue by bringing several researchers from a variety of European Commission financed research projects together with policy makers and business stakeholders to discuss their most recent findings.

Three sessions structured the roundtable where the emphasis laid on fruitful discussions and exchanging ideas facilitated by Dr. Bert Metz of the European Climate Foundation (ECF). The first session tackled the issue of policy interactions at the EU as well as Member State levels; session 2 scrutinised the role of small and medium-sized enterprises (SMEs) in innovation for in a low-carbon economy; and session 3 looked at cities and their strategies of tackling climate change and some illustrative examples were presented from the city of Turin among other urban examples.

During the roundtable, many areas for future research were identified, particularly on the bioeconomy and the agricultural sector. Yet, the dialogue also clearly demonstrated that research is often constrained by what is politically possible. This, however, should not restrain research but, on the contrary, incentivise researchers to tailor research better to the knowledge needs of policy and business stakeholders, to provide solutions to the 21st century's most pressing issue.

A more extensive report of the workshop will be published on the CARISMA website as a blog post shortly.

GOING BEYOND LCOE: ASSESSING THE **SYSTEM IMPACTS** OF RENEWABLES

In May 2017, the CARISMA project will publish a report on the (re)assessment of costs for selected renewable energy technologies, with the goal of incorporating the recent discussion of system and macroeconomic costs of those technologies into the narrower view of levelised cost of electricity (LCOE).

Gabriel Bachner & Andreas Türk, University of Graz

Within the CARISMA project, costs and benefits are analysed of a number of climate change mitigation technologies.

The report evaluates the coverage and reliability of existing data (cost-benefit scenarios and assessments) for selected technology options, and conducts the relevant assessments where existing literature is found to be insufficient. We use the recent discussion on the shortfalls of LCOE for renewables as a way to frame and motivate our assessment. Starting with an overview of the current direct costs of renewables, the report expands upon current assessments and incorporates system costs, the additional costs incurred by renewables being incorporated into the larger energy grid and costs of energy storage in case of intermittent renewable energy sources, as well as the macroeconomic effects of deploying renewables at larger scales, capturing the indirect effects due to interlinkages between economic sectors and agents. Methodologically we use a multi-regional multi-sectoral computable general equilibrium (CGE) model to assess the system impacts of renewables deployment into the broader economy, to assess social costs and benefits, and to help compare cost and benefit attributes across different mitigation pathways and regional contexts. The work includes wind and solar PV and analyses high penetration targets (one quarter of the EU's electricity demand is generated by new wind or PV facilities) up to 2030. For bio-energy with CCS (BECCS), a separate report will be released later.

The report concludes that the direction of regional welfare effects depends on (i) relative generation costs of electricity generation technologies, (ii) relative capital intensity of generation technologies, and also to a considerable part on (iii) integration costs that have so far been neglected in macroeconomic assessments. These include 'balancing costs' arising form deviations from day-ahead generation schedules, for example forecast errors, 'grid-related costs' that emerge due to geographical reasons, transmission constraints and losses, and 'profile costs', that are the result of increased ramping and cycling (the 'flexibility effect') and reduced utilisation of thermal plants (the 'utilisation effect').

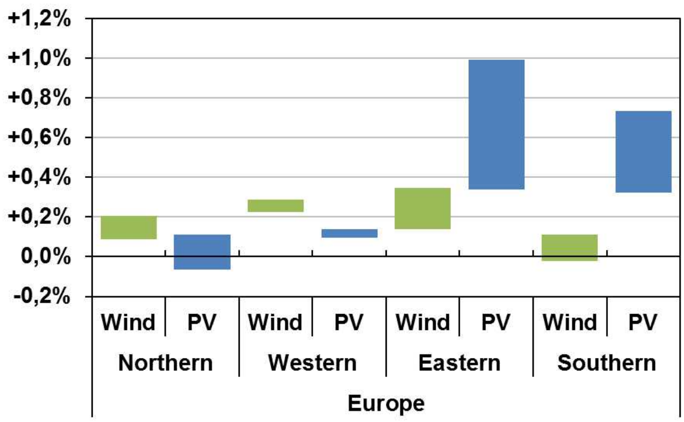

Figure 4. Ranges of possible welfare effects (Hicksian Equivalent Variation) based on combinations of high/low-WACC and boom/recession assumptions; including integration costs.

The preliminary results of the analysis show that the welfare effects of expanding wind/PV to large penetration rates are mostly positive. However, the effect of integration costs may be so strong that in some countries potential positive welfare effects can become negative, even though the generation costs of wind/PV from a pure LCOE perspective appear to be lower than the currently prevailing electricity mix. Thus, traditional LCOE assessments and comparisons across electricity technologies can be misleading when integration costs and macro-economic effects are neglected. The discussed effects of the expansion of large scale wind and PV are subject to large uncertainties, especially concerning the following points: (i) expected cost developments for wind and PV, (ii) assumptions on the weighted average costs of capital (WACC) and (iii) whether the assumed expansion happens in a boom or a recession phase. The respective bandwidths of preliminary welfare effects are given in Figure 4.

The role of integration costs may decrease over the next years, if the energy system shifts to increasingly decentralised structures, and an integration of renewables into the wholesale markets (as it was analysed in the macro-economic assessment) may not be so important anymore. However also decentralised energy system may cause integration costs depending on the mix of technologies used and the resulting need for back-up capacities. The impacts on integration costs therefore need to be carefully assessed if decentralised solutions should not lead to business economic but also macroeconomic and societal benefits.

The report on economy-wide deployment costs and benefits of renewable energy technologies, incorporating system costs and macroeconomic effects, will be published on the CARISMA website in May 2017.

WHAT TYPES OF **CONTEXTUAL FACTORS** MATTER TO CLIMATE CHANGE MITIGATION POLICIES?

As introduced in CARISMA Monitor No. 7 (November 2016), the CARISMA project focuses on the contexts affecting formulation and adoption of climate change mitigation policies and policy instruments.

A CARISMA Discussion Paper was published that seeks to contribute to the understanding of the factors that constitute a context for the formulation and implementation of a policy instrument. Although these contexts are highly complex, better awareness and understanding could enable policy-makers to design policy instruments to be more robust and adaptive to changes in contextual frameworks.

Derived from institutional, economic, and social contexts, the paper identifies three types of contextual factors: institutions and governance; innovation and investment; and attitudes, behaviour, and lifestyle. The paper suggests some preliminary solutions to the challenges related to the contextual factors.

Institutions and governance: The need for regulatory alignment is recognised. While EU impact assessments of mitigation options have largely limited the focus to regulatory alignment of climate and energy policies, future assessments could also look at the need for alignment between climate and non-climate regulations. It is also important to ensure coherence and closer coordination between the relevant authorities and between different levels of government.

Noriko Fujiwara,
Centre for European Policy Studies (CEPS)

Within the CARISMA project, CEPS leads the work on the roles of implementation and contextual factors in realising climate change mitigation.

Innovation and investment: One way forward is to strategically support clusters and regional collaborative networks as hubs of knowledge creation and dissemination, with a view to establishing a technology innovation system. There is need for an enabling regulatory framework and for policy continuity.

Attitudes, behaviour and lifestyle: Early education (e.g. school curriculum) could make difference. Well-educated and informed children may influence the attitudes and behaviour of their parents and other members of their local community. Another effective action in the research community would be categorisation and more thorough examination of demographic features of target groups in order to better inform policy-makers at both the national and sub-national levels.

The Discussion Paper can be downloaded from the CARISMA website. The categorisation of contextual factors will be used for the analysis of governance case studies in various European countries during the next phase of the project.

PATHWAYS TO LOW-CARBON SOCIETIES

There are many case studies on local and regional transitions. Until recently, an overview of such case studies was missing. The PATHWAYS project has created a database that allows for sharing information on European case studies, in order to foster reuse of the knowledge gained in previous studies.

TRANSITION PATHWAYS TO SUSTAINABLE LOW-CARBON SOCIETIES

EU-funded research on reducing emissions

CLIMATECHANGE MITIGATION.EU

FEATURED PARTNER PROJECT. PATHWAYS is one of the 13 EU-funded climate change mitigation research projectscurrently involved in the online ClimateChangeMitigation.eu portal (see also page 7).

PATHWAYS has explored the possibilities for transitions to a low-carbon, sustainable Europe. The essence of PATHWAYS is that it combines the analysis of different scientific disciplines: integrated assessment modelling, socio-technical transition analysis, and initiative-based learning. By combining and coordinating information from these different disciplines for selected cases, PATHWAYS aims at providing better policy advice for European, Member State and local policy-makers.

In the framework of the project, the PATHWAYS team has compiled a database of relevant case studies on transitions to sustainable low-carbon societies. The case studies are on various scales (from city or even neighbourhood level up to national and EU level) in countries throughout Europe. The case studies are in the domains of transitions related to buildings, education, energy, food/agriculture, heat generation, land use/nature, transport, waste/resource management, and water. The database, that includes both case studies developed by the PATHWAYS project and external case studies, is available online on the project website: PATHWAYS Transition case study database.

"CLIMATE CHANGE **MITIGATION**: OPTIONS AND POLICIES" **SUMMER SCHOOL** IN NIJMEGEN, THE NETHERLANDS

The EU-funded CARISMA project on innovation for climate change mitigation and the UN Climate Technology Centre & Network (CTCN) jointly organise a summer school course on climate change mitigation. The course will take place from 14 through 18 August 2017 as part of the Radboud Summer School programme in Nijmegen, the Netherlands. The course is targeted at post-graduates, PhD students or junior professionals in public service working on the topic of climate change mitigation.

The city of Nijmegen, the Netherlands.

SUMMER SCHOOL ON MITIGATION

Climate change mitigation, i.e. human intervention to reduce greenhouse gas emissions or enhance sinks of greenhouse gases, is firmly on the international policy agenda since the Paris Agreement of 2015. For meeting the Paris Agreement goals, an acceleration will be required of global development, deployment and diffusion of technologies and practices for mitigation. The summer school course will take a multidisciplinary perspective and discuss climate mitigation technologies, practices, costs and benefits as well as related policies and needed governance.

In short, the course starts with an introduction on technology transfer for climate change mitigation: what are potential technology options for reducing greenhouse gas emissions, what are their climate footprints, what are cost items to consider, how to enhance public acceptance, and what R&D activities exist (are needed) to accelerate development, deployment and diffusion of technology options?

As part of the course, an interactive workshop will be organised by the UN Climate Technology Centre & Network (CTCN), introducing students into technology transfer practice, with a specific focus on developing countries. Based on concrete examples, students will work in small groups on case studies about how to prioritise sectors and technologies for mitigation within different country contexts. The final part of the programme contains lectures on policies and governance for technologies for mitigation, including a key note lecture by a senior policy practitioner on technology transfer from an international climate policy and negotiation perspective.

SUMMER SCHOOL SOCIAL PROGRAMME

Radboud Summer School is more than an academic event. It is a unique opportunity to meet other international students and researchers and to get to know Radboud University and the city of Nijmegen. Participants of the course on mitigation and the more than 50 other courses come from all over the world and have different cultural and academic backgrounds. The programme includes the following activities free of charge: welcome reception, sports activity, guest lecture, pub quiz and farewell drink. A barbecue, river cruise, city tour and excursion are offered for a small fee.

APPLICATION

The deadline for application for the summer school course is 1 June 2017, with an early-bird registration open until 9 May 2017. Up to five participants from developing countries may be financially supported to attend the summer school by the CARISMA project (please indicate in your motivation letter if you need this). More information, a preliminary programme, and the registration link are available at the Radboud Summer School website: ru.nl/radboudsummerschool.

CARISMA PROJECT UPDATES

Blog on the Austrian Electricity Act. Keith Williges's blog post 'Course Correction: 2017 Amendments to the Austrian Electricity Act' has been published on the CARISMA website. He explains that the recent passage of the Green Electricity Act in Austria serves as a convenient example of how policymaking is influenced by institutional, economic, and social context factors. See also the article on CARISMA's work on contextual factors on page 5.

EU climate and energy policy interactions. The CARISMA case study analysis on energy and climate policy interactions aims to complement existing literature on policy interactions by addressing a set of aspects of policy interactions related to: the policy levels at which interactions may occur (EU, national or regional levels), inter-temporal interactions (e.g., short term versus long term policy interactions), and interactions that occur if stakeholders are indirectly affected by a policy instrument (even if they are explicitly excluded from the policy). A working document is available on the CARISMA website.

Mapping of EU mitigation efforts. Many models exist predicting whether and how climate targets could be met, but no up-to-date knowledge exists on the actual efforts taken by the EU and its Member States to commit to this target. One year after the Paris Agreement, researchers of the CARISMA project mapped the mitigation efforts of the EU and its neighbouring countries to provide rough-and-ready estimates of whether mitigation targets can be reached. The point and aim of this mapping exercise is not comprehensiveness, but a first reality check of current European mitigation efforts. The questions answered are: What were the RD&I activities aimed at climate change mitigation in the EU and Member States that underwent since 2007 up to 2015? Which types of organisations performed them? The results of the mapping exercise will be published as a Policy Brief on the CARISMA website shortly.

Monthly update on EU-funded mitigation research. The CARISMA project every month circulates an email on the latest highlights on EU-funded research on climate change mitigation, as posted on the ClimateChangeMitigation.eu portal (see below). Register for this monthly update via climatechangemitigation.eu/update.

Workshops on international R&I collaboration. In the framework of the CARISMA project, three workshops are organised on international collaboration on research and innovation (R&I) for climate change mitigation. In March 2016, the first workshop in Copenhagen focused on firm-level outsourcing and offshoring of R&I activities to emerging economies. In February 2017, the main topic of the second workshop in Amsterdam was on regional-level, government-to-government, and industry-specific R&I initiatives (see page 3). The third and final workshop in the series will take place as a side-event of the Bonn Climate Change Conference on 18 May 2017. More information will be available on the CARISMA website shortly.

Online portal for EU-funded mitigation research

Last year, the CARISMA project launched an online portal on climate change mitigation. The portal has been developed together with other EU-funded projects, and aims to enable the exchange of information on mitigation research and innovation. The projects post highlights of their work so that information from different EU-funded research and coordination projects relevant to mitigation can be easily accessed in one place.

The portal covers a range of mitigation-related topics, including mitigation technologies and practices, scenarios and models, links to relevant data sources, case studies, policy information, and issues on stakeholder engagement.

In addition to CARISMA, twelve other EU-funded mitigation research projects have become involved (see page 5 for more information). Other relevant projects are welcome to join to share their research highlights.

The online portal is available at www.climatechangemitigation.eu, and for relevant updates the #mitigationEU hashtag is used on Twitter.

CARISMA
Innovation for Climate Change Mitigation

The CARISMA project intends to ensure a continuous coordination and assessment of climate change mitigation options.

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